VI. THE COPROLITE LIMESTONE HORIZON OF THE CONEMAUGH SERIES IN AND AROUND MORGANTOWN, WEST VIRGINIA.*

By Paul Holland Price.

(PLATES X–XXI.)

"Man measures his life by a few score of years, but the years of the earth are measured by many millions, an abyss of time, so vast in comparison, that the mind cannot fathom it save by analogy."
—Barrell.

INTRODUCTORY.

Science has proved that mountains are transitory forms and are ever changing, but the individual through a lifetime sees little or no change. This is as true at Morgantown as elsewhere. Close observation, however, shows that changes have continuously been going on in the past and are still taking place. If the layman will take the trouble to observe the excavations for sewers which go on in the streets of Morgantown, he will see uncovered beautifully rounded stones and boulders from a few inches to a foot or more in diameter. They are just like those which may be seen at the bottom of running streams. This old buried gravel is accepted as having been deposited where it now lies at a much earlier date than the gravels in recent streams. It was laid down when the Monongahela River and Deckers Creek united in forming a flood-plain, or, in other words, when the present streams flowed at a higher level than they now do. This terrace, upon which most of the Third Ward of Morgantown is located, has an elevation of from 885 ft. to 890 ft. above sea-level, while the present elevation of the Monongahela River at the mouth of Deckers Creek is 800 ft. above sea-level. During the lifetime of "the oldest inhabitant" there has been no noticeable change in the level of the river above the sea. How long then has it taken these streams to cut down through these 90 feet of solid material, more than half of which consists of the hard and resisting Buffalo Sandstone,

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which can be seen exposed to view at the southern end of the High Street Bridge! This is only one example of what the streams have been doing in the vicinity; there are many others. The deposits of clay and sand on the "Flats" along the Star City road, with an elevation of 1035 ft. above sea-level, represent the bed of another ancient river. Below this level there are terraces which reveal the levels on which the river flowed at later periods. A good illustration of these river terraces is shown in Morgantown, where the University of West Virginia is located upon an upper terrace; the United States Postoffice upon a lower terrace; and the Baltimore and Ohio Railroad upon a still lower terrace. The formation of these terraces and even the life of the Monongahela River itself are recent, compared with the date when the strata were formed from which the fossils described in the following pages were taken. As a matter of fact there was no such river as the Monongahela in existence then, but the area was covered by a shallow inland sea, or lake.

The age of the Pittsburgh Coal seam has been roughly estimated at one hundred millions of years. This, of course, is not an absolutely accurate estimate, as some lines of evidence suggest an even greater age. The fossils, with which this paper deals, come from a level approximately four hundred feet lower than the Pittsburgh Coal, and therefore from a stratum as much older as the time which would be required for the deposition of the four hundred feet of shale, sandstone, limestone, and coal which intervene. A geologic time-table arranged by George H. Ashley, the time-scale from Joseph Barrell with slight modifications is here given.[1]

ERAS	AGES	
CENOZOIC (Recent Life) Era of Mammals	QUATERNARY 1 million years	Age of Ice and Man
	UPPER AND LOWER TERTIARY 60 million yrs.	Age of Mammals Evolution of Primates Maximum thickness of strata, 40,000 ft.

[1] *Cf.* Josiah Edward Spurr, "The Ore Magmas" (McGraw-Hill, publishers) 1923, Vol. I, p. 396.

MESOZOIC (Middle Life) Era of Reptiles	UPPER AND LOWER CRETACEOUS[2] 75 million yrs.	Culmination of Reptiles. Maximum thickness of strata, 50,000 ft. Thickness in Montana, 24,000 ft. (Lower Cretaceous only); Thickness in California, 26,000 ft. (Upper Cretaceous only).
	JURASSIC 40 million yrs.	Age of Reptiles Evolution of Birds Maximum thickness of strata, 18,000 in California.
	TRIASSIC 40 million yrs.	Increase in Reptiles Evolution of Mammals Maximum thickness of strata, apparently 20,000 to 30,000 ft. in Pennsylvania.
UPPER PALEOZOIC (Upper Ancient Life) Era of Fishes and Amphibians	CARBONIFEROUS (Permian, Pennsylvanian,[3] Mississippian). 115 million yrs.	Age of Coal Age of Amphibians Evolution of Reptiles Maximum thickness of strata, 24,000 ft. in Arkansas; average 4,500 ft. plus.
	DEVONIAN 50 million years	Age of Fishes Evolution of Amphibians Maximum thickness of strata, 13,000 ft. in Pennsylvania; Average 3,000 ft.
	SILURIAN 40 million yrs.	Development of Fishes Invertebrates Maximum thickness of strata, 7,300 ft. in Massachusetts; Average 2,000 ft.

[2]Approximate age of the present Monongahela River, as it flowed northeast through the Gulf of St. Lawrence to the Atlantic before the advance of the last great Ice-sheet, but the river had its origin upon the Cretaceous or Jura-Cretaceous peneplain.

[3]Age of Fossils described in this paper.

LOWER PALEOZOIC (Lower Ancient Life) Era of Invertebrates	ORDOVICIAN 110 million yrs.	Age of Invertebrates Evolution of Vertebrates Maximum thickness of strata, 15,500 ft. in Mass.; Average 3,000 ft.
	CAMBRIAN 90 million yrs.	Reign of Invertebrates Maximum thickness of strata, 40,000 ft. in British Columbia; Average 4,000 ft.
PROTEROZOIC (First Life)	ALGONKIAN Time probably as long as all of the Paleozoic.	Evolution of Invertebrates Maximum thickness of strata, 74,000 ft. in Canada; in Rockies, 37,000 ft.
	ARCHEAN Time not estimated but very long. No known beginning to this division.	Maximum thickness of strata, 74,000 ft. in Canada.

GENERAL.

A search begun in the year 1923 and since continued has revealed an abundance of vertebrate remains, particularly coprolites of fishes, and a few coprolites containing fish-scales, which may be of amphibian or reptilian origin. In addition there have been found teeth, scales, spines, and other remains of fishes. It has been thought advisable to describe and illustrate these, since there has been no previous collection of coprolites from the formations of West Virginia.

The writer has at hand in the office of the West Virginia Geological Survey more than a thousand specimens of the excrement of fishes some of which are much better preserved than others. Many of these have inclusions of teeth and scales which retain their original character. Nearly all the specimens in the collection are of the spiral form, since much of the material, which plainly was excrement, but without special shape, was not saved.[4]

Scales of the rhombic type are abundant, both plain and striated.

[4]The writer has taken pleasure in communicating to the Carnegie Museum a number of specimens from this collection (C. M. Acc. No. 8,003) (Cat. Vert. Foss. No. 5418) in recognition of the kindness of that institution in publishing the results of the studies made by the author.

Teeth are scattered throughout the limited horizon. There are thirty-five to forty small conical teeth of the *Paleoniscus*-type, and ten to twelve specimens of the *Diplodus*-type.

As yet no complete skeleton has been found, but with such an abundance of material, along with fragments of spines, it is expected that further search may be rewarded by the discovery of such fossils, although the very friable nature of the matrix does not encourage this hope. It is believed that the publication of this paper may increase general interest in the Vertebrate Paleontology of our region and it is requested that such discoveries as are made, may be brought to the attention of the members of the Geological Survey of West Virginia, or of the Staff of the Carnegie Museum.

Geographic Location. The extent of the "Coprolite Limestone Horizon" has not yet been definitely determined, as its known occurrence is limited to six localities, all within one and one-half miles from Morgantown. Some attempts have been made to correlate with more distant areas, but without success. Further search may prove it to be of greater extent than now observed. These fossil localities are shown on the Topographic Map, Plate X. The localities are numbered in the order of their discovery: 1, W. V. U. Stadium; 2, Keck's Quarry, Westover, W. Va.; 3, Athletic Field of the New High School; 4, Morgantown Brick Plant; 5, Red Bridge near Fairmor; 6, Ravine below East Morgantown fill.

Geologic Horizon. The "Coprolite Limestone Horizon" was first discovered by the writer in 1923, and in the following year a brief description of it was given in an Academic Report to Professor E. R. Scheffel. The horizon was first detected in Falling Run Hollow, when excavation was begun for the Stadium of the West Virginia University. At the suggestion of David B. Reger a detailed section was made at this locality, where the new fossiliferous horizon was found. Its horizon having been thus determined, it was traced to the other localities above mentioned.

The "Coprolite Limestone Horizon" lies in the Pittsburgh Red Shales (Round Knob), between the Pine Creek (Cambridge) and the Ewing Limestones, or in the lower half of the Conemaugh Series of the Pennsylvanian System.

Description. The limestone for which the horizon was named is merely a *marker* for the fossiliferous shale. It contains no coprolites, but does have an abundance of fresh-water *Serpulæ*. It may be described as a dark, gray-blue, fine-grained, crystalline limestone, from one to two feet thick. It contains considerable iron in the form of marcasite, which gives it a ferruginous stain upon weathering; where it crops out at the Athletic Field of the New High School it is somewhat nodular. From its general appearance it could easily be mistaken for the Pine Creek (Cambridge) or the Ewing Limestone, unless carefully examined for fossils.

The coprolite horizon proper comes directly over this limestone, and can be described as being a carbonaceous and slightly calcareous shale, from three to six inches thick, which contains an abundance of fish remains, such as coprolites, teeth, and scales. Occasionally the remains of plants also are discovered. At the Stadium locality (No. 1) a well preserved *Pecopteris* was found.

Petrography. As previously stated, the limestone is referred to only as a marker for the coprolite horizon proper. It is a dark siliceous limestone from one to two feet thick, containing numerous fresh-water fossils (*Serpula*). The overlying horizon, which contains the vertebrate fauna, is a fine-grained, calcareous and carbonaceous, gray-blue shale. When wet it is plastic, but upon weathering readily disintegrates. The microscope reveals the following constituents in the order of their importance: kaolin; marcasite; fragments of contemporaneous sandstones; limonite, (partly as a cement); quartz (as sand-grains); carbon (particles of coal); calcite; and muscovite.

The kaolin constitutes the greater part of the formation (at least half of which passed through a two hundred mesh screen), and is decomposed feldspar, which came from an old crystalline ground-mass to the east and southeast. The marcasite is not evenly distributed, but is concentrated in patches and often centers around, or entirely covers, a coprolite. The grains of sand are fairly well rounded, indicating that they had been carried some distance from their source. Carbonaceous particles are scattered throughout, giving the formation its dark color. Fragments of coal and sandstone indicate some contemporaneous erosion. Limonite is most common as a cement, and is also present in small particles. The mica (muscovite) flakes are scarce.

Correlation of Horizon. It was at first supposed that this horizon was the same as the Ewing Limestone of Ohio. There the Ewing is described as follows:[5] "Beneath the Barton coal is clay and more or less limestone in the form of nodular or continuous layers. The limestone is much more persistent than the coal and is found nearly everywhere, except in places where it has been eroded and its horizon occupied by sandstone. Ordinarily there is only a nodular layer a foot or so thick, or a single course of limestone less than two feet thick, but here and there in the eastern part of the state are areas where the limestone attains a thickness of five to ten feet and consists of a number of layers interlaid with clay. Fossils of types generally regarded as fresh-water are abundant in the Ewing limestone. *Spirorbis* is the most numerous of these and ostracod carapaces are next in abundance. Fish teeth are not uncommon, and reptilian bones are also present."

This description along with the fossils is suggestive of the same horizon, which is found here with coprolites, the teeth of fishes, etc. However, a limestone, which outcrops in the basement of what is now the Masonic Temple and is believed by Dr. I. C. White to correspond to the Ewing, did have a number of *Spirorbis* present, but the overlying dark shale, which would contain the coprolites, was absent.

There have been discovered a number of amphibian and reptilian bones from the lower part of the Pittsburgh Red Shales near Pittsburgh, Pennsylvania.[6]

It can therefore be seen that the lower Conemaugh Series has revealed and will continue to reveal many vertebrate remains, but the changing conditions, the lensing, and entire disappearance of certain horizons, make the correlation at least for any great distance rather uncertain. It seems to be a duplication of conditions at numerous localities, rather than a continuous deposit. However, with more detailed work, it may later be possible to definitely correlate the "Coprolite Limestone Horizon" with some of the horizons, which have previously been recognized as containing vertebrate remains.

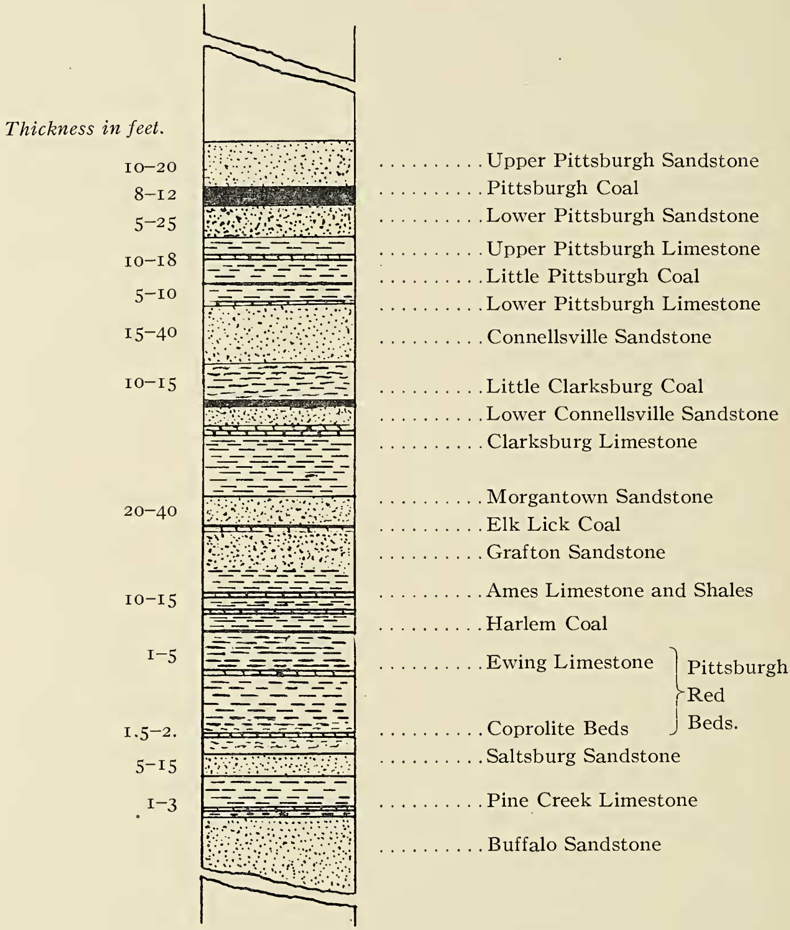
[5] "Conemaugh Formation" by Condit. Fourth Series, Bull. 17, Ohio Geological Survey, 1912, pp. 37–39.

[6] "Description of Vertebrate Fossils from the Vicinity of Pittsburgh, Pennsylvania," by E. C. Case. Annals of Carnegie Museum, Vol. IV, 1908, pp. 234, *et seq.*

FIG. 1. Columnar section showing position of Coprolite Limestone Horizon.

(Scale: 1 inch = 125 feet.)

BY PAUL H. PRICE.



Intervals of Coprolite Limestone Horizon above and below other well known strata:

Pittsburgh Coal	375–400	ft.
Ames Limestone and Shales	75–90	ft.
Ewing Limestone	25–40	ft.
COPROLITE LIMESTONE HORIZON	0–0	ft.
Saltsburg Sandstone	15–15	ft.
Pine Creek Limestone	45–50	ft.
Top of Buffalo Sandstone	50–55	ft.

COPROLITES OF FISHES.

It has long been known that many fishes possess a spiral intestinal valve, which imparts to the extruded feces a form, which is somewhat

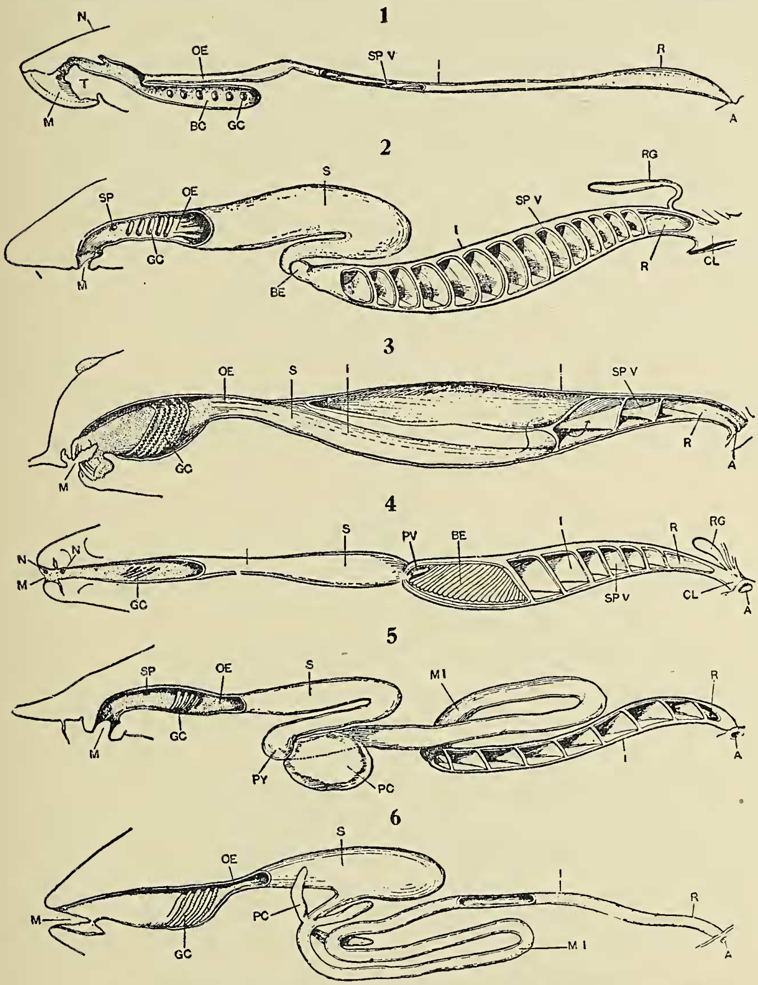


FIG. 2. Digestive tracts of fishes: 1, Cyclostome (*Petromyzon*); 2, Shark; 3, Chimæroid (*Callorhynchus*); 4, Lung-fish (*Protopterus*) after W. N. Parker; 5, Ganoid (*Acipenser sturio*); 6, Perch, after Wiedersheim.

A, anus; BC, branchial chamber; BE, *Bursa entiana* (duodenum); CL, cloaca; GC, gill-openings; I, intestine; M, mouth; MI, mid-gut; N, nares, anterior and posterior; OE, œsophagus, or gullet; PC, pyloric cœca (pancreas); PY, pyloric end of stomach; R, rectum; RG, rectal gland; S, stomach; SP, spiracle; SPV, spiral intestinal valve.

variable according to the arrangement of the valve. Under favorable conditions the form of the feces retains outlines which are characteristic. Fig. 2, which is here reproduced from Dr. Bashford Dean's "Fishes Living and Fossil," in the five upper illustrations shows the outline of the spiral valve of the intestine as it exists in five well known families of fishes. A little reflection makes plain that the passage of the material, which is not digestible, but is destined to be voided as feces, through such a spiral valve must impart to such material a spiral or coiled form, before it is ejected through the rectum and anus. It also is plain, that, the greater the number of the chambers in the intestinal valve, the greater the number of coils in the feces, provided always that the food-supply is abundant. Almost all of the coprolites shown in the plates accompanying this paper show a more or less spiral or coiled structure. (See Plates XI–XVI). The spiral structure of the coprolites is also revealed by cross-section (See Plate XVII). This spirality may be perhaps better shown by the accompanying text-figure (Fig. 3) which is based upon several cross-sections made by the writer.

FIG. 3. Diagrammatic cross-section of coprolite of a fish.

Neumayer[7] in his paper, "Die Koprolithen des Perms von Texas," has divided his specimens into two general groups, called by him "Heteropolaren" and "Amphipolaren," the divisions being based upon the position of the rings formed by the successive layers. Those on which the rings are limited to the anterior half of the coprolite are heteropolar, while those on which the rings extend farther along and even to the posterior end of the coprolite are amphipolar.

The question may at this point be raised whether or not fecal matter, which at the time of its passage belongs to the heteropolar type, upon being exposed for a short time to the action of water, may not unfold itself enough to be later embedded as of the amphipolar type. It is the opinion of the writer that this might happen, and some of the specimens at hand seem to favor this idea (See Plates XI-XIV).

[7] L. Neumayer: *Die Koprolithen des Perms von Texas.* Paleontografica, Vol. LI, 1904–5, pp. 121–127, 1 plate.

Whether or not the number of spirals in the digestive tract of fishes absolutely determines the number of spirals in the excrement is problematical. Whether it is possible to determine the genus of a fish from the number of spirals in the excrement is still more problematical. There appears, however, to be a measure of regularity in the number of spirals in the coprolites composing the present collection. The scales and particularly the teeth of fishes, which have been found with the coprolites represent at least two distinct types of fishes. The teeth may be referred to the ganoid *Paleoniscus* and to the genus *Diplodus* Agassiz. Associated with the scales and teeth of these are at least two distinct types of excrement: one generally showing five coils, some distance apart; the other having many more, lying close together. Since the intestinal valves in the digestive tract of ganoids are few in number (four to seven), while in the sharks, to which *Diplodus* is allied, have many, it may not be illogical to infer that the coprolites which have few turns in the excrement represent fishes of the type of *Paleoniscus*, and that those which have many represent fishes of the type of *Diplodus*. (See text-figure 2.)

COPROLITES OTHER THAN THOSE OF FISHES (?).

The two large coprolites shown on Plate XVIII, figs. 1 and 2, were found associated with the other material described in this paper. Both specimens contain small rhombic fish-scales of the ganoid type, which the writer has referred to the genus *Paleoniscus* (See *infra*). The specimen shown on Plate XVIII, fig. 1, although not entire, is divided by a median impression into two lobes, the constriction being at right angles to the direction of passage. The coprolite represented on Plate XVIII, fig. 2, is marked by a median groove on two sides, parallel to the direction of passage. It is shown on the plate of natural size.

So little is known of the voided excrement of the extinct amphibia and reptilia, and for that matter of the amphibia and reptilia of the present, that it seems hazardous to predicate amphibian or reptilian origin to these specimens. Nevertheless, in view of their great dissimilarity to the coprolites of fishes depicted on the plates, and the fact that both amphibian and reptilian remains have been discovered at approximately the same geological horizon near Pittsburgh,[8] it seems not to be a wholly illogical surmise to say that these objects may be

[8]See foot-note 6.

of amphibian or reptilian origin, or both. This suggestion is set forth by the writer with diffidence, especially in view of the very scanty information which thus far has been obtained as to the life-history and habits of the amphibia and reptilia of the Carboniferous and Permian ages.

THE DIMENSIONS OF THE COPROLITES OF FISHES.

The coprolites shown upon the plates accompanying this article are all displayed, with but one exception, as more or less magnified. It has therefore seemed proper to give in tabular form a statement of the exact length and thickness of a representative series of specimens.

Table Showing Relation Between Length and Thickness of a Number of Representative Coprolites from the Conemaugh Formation.

Pl. XI.

Fig.	1	L.	14.7	T.	6.7
"	2	"	16.7	"	7.4
"	3	"	15.4	"	7.4
"	4	"	15.4	"	6.7
"	5	"	14.0	"	6.7
"	6	"	16.0	"	6.0
"	7	"	15.4	"	6.7
"	8	"	14.0	"	6.7
"	9	"	16.0	"	7.4
"	10	"	16.7	"	6.7
"	11	"	14.7	"	5.4
"	12	"	18.7	"	6.7
"	13	"	14.0	"	5.7
"	14	"	16.7	"	6.0
"	15	"	16.7	"	6.0
"	16	"	15.4	"	5.7
"	17	"	15.4	"	6.7
"	18	"	13.4	"	6.0
"	19	"	12.7	"	7.4
"	20	"	10.4	"	5.4
"	21	"	13.0	"	6.0
"	22	"	15.4	"	6.0
"	23	"	17.4	"	4.7
"	24	"	12.7	"	6.7
"	25	"	15.4	"	4.7
"	26	"	14.7	"	7.4
"	27	"	14.0	"	6.0
"	28	"	12.4	"	6.0
"	29	"	13.4	"	5.4

Pl. XI.

Fig.	30	L.	14.4	T.	6.0
"	31	"	15.0	"	6.0
"	32	"	14.7	"	5.4
"	33	"	14.7	"	5.4
"	34	"	14.7	"	5.4
"	35	"	12.7	"	6.4
"	36	"	15.4	"	5.7
"	37	"	14.0	"	6.7
"	38	"	15.7	"	6.4
"	39	"	17.4	"	6.4
"	40	"	17.4	"	6.0

Pl. XII

Fig.	1	L.	12.	T.	6.0
"	2	"	14.7	"	7.4
"	3	"	13.4	"	6.7
"	4	"	14.7	"	5.4
"	5	"	11.7	"	5.7
"	6	"	15.0	"	5.4
"	7	"	16.4	"	4.7
"	8	"	16.0	"	5.4
"	9	"	15.7	"	6.4
"	10	"	10.0	"	7.4
"	11	"	20.4	"	7.4
"	12	"	24.0	"	5.7
"	13	"	21.4	"	6.0
"	14	"	21.4	"	7.0
"	15	"	22.0	"	10.0
"	16	"	16.6	"	6.7

Pl. XII.

Fig.	17	L.	18.7	T.	7.4
"	18	"	16.6	"	6.0
"	19	"	14.0	"	6.0
"	20	"	12.7	"	5.4
"	21	"	19.0	"	6.0
"	22	"	19.0	"	6.0
"	23	"	16.0	"	8.0
"	24	"	18.4	"	7.4
"	25	"	19.7	"	9.4
"	26	"	15.7	"	6.0
"	27	"	15.7	"	5.7

Pl. XIV.

Fig.	1	L.	16.7	T.	6.0
"	2	"	15.4	"	6.0
"	3	"	17.0	"	8.0
"	4	"	16.0	"	6.0
"	5	"	16.6	"	6.7
"	6	"	16.0	"	6.0
"	7	"	18.7	"	8.0
"	8	"	18.4	"	7.7
"	9	"	19.0	"	8.7
"	10	"	18.0	"	6.0
"	11	"	16.0	"	8.0
"	12	"	19.0	"	9.4
"	13	"	20.0	"	6.7
"	14	"	20.0	"	10.7
"	15	"	26.7	"	9.4
"	16	"	23.2	"	9.4
"	17	"	20.7	"	14.7

These figures represent more nearly the average than they do the extremes. It can be seen that some are short and thick, while others are long and slender.

COPROLITES SHOWING BURROWS OR BORINGS.

When a worm burrows and eats its way into compact earth or excrement, the hole remains for some time, and finer material will later fill it. That this has taken place in at least twenty-four of the coprolites at hand is highly probable. (See Plate XVI.) The first assumption that the holes are concretionary, or openings left by some displaced particle, such as a grain of sand or other foreign material, is dismissed in favor of worm-borings. These holes vary somewhat in depth and in width, but are generally very regular in their appearance. They vary in width from one to two millimeters, and in depth from two to three millimeters. The holes or borings have all been refilled with fine soft mud, which is entirely different from the content of the excrement, but similar to the matrix of the coprolitic horizon.

MINERALOGY AND CHEMICAL CONSTITUTION OF COPROLITES.

A microscopic examination of thin sections and polished specimens of coprolites reveal many interesting features. They are composed of partially digested food, which has since carbonized; fragments of bone, represented by brownish white inclusions; while teeth and scales are scattered throughout the sections.

That these coprolites are silicified to any great extent, as is the case with many which have been obtained elsewhere, is not borne out by chemical analysis (See below). It is true that silica is present, but it averages only about one-tenth of the whole. The principal constituent, however, as might be expected from the food of fishes, is calcium phosphate, averaging about one-half of the entire content. It is possible that some of the calcium phosphate may be secondary, derived from circulating waters; but it is the belief of the writer that the most of it was present in the undigested particles of bone, teeth, and scales.

Six examples of coprolites have been subjected to chemical analysis. They are:

Sample No. 1. Fish Coprolite.
Sample No. 2. Fish Coprolite encrusted with Iron Sulphide.
Sample No. 3. Coprolite (Amphibian?).
Sample No. 4. Amorphous excrement, fish or amphibian.
Sample No. 5. Several fragments of fish coprolites. (Locality, Morgantown Brick Plant.)
Sample No. 6. Fish Coprolites. (Locality, Athletic Field of New High School.)

The analyses here follow:

CHEMICAL ANALYSES OF COPROLITES.

(Made by B. B. Kaplan, Chemist.)

Material of Contents	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Sample No. 6
Silica (SiO_2)	9.85	4.00	11.00	8.80	17.20	9.40
Iron Sulphide (FeS_2)	5.83	17.12[9]	2.69	3.83	9.02	1.47
Alumina (Al_2O_3)	2.96	2.10	3.70	3.30	4.70	2.96
Calcium Carbonate ($CaCO_3$)	24.76	25.80	35.58	35.16	27.14	40.10
Calcium Phosphate ($Ca_3(PO_4)_2$)	50.21	44.18	40.85	43.87	35.73	40.43
Organic Matter	4.95	....	....	....	....	....
Moisture	0.96	1.05	0.88	1.20	0.70	1.12
Loss on Ignition	....	5.12	5.22	3.85	5.05	4.65
Total	99.52	99.37	99.92	100.01	99.54	100.12

The Phosphoric Acid included in the Calcium Phosphate is:

Phosphoric Acid (P_2O_5)	22.99	20.27	18.70	20.40	16.62	18.80

It is interesting to note the comparison of the analyses of the coprolites we are studying with the composition of *Collophane.* In a paper on "The Mineralogy and Petrography of Fossil Bone"[10] Rogers has shown that fossil bones are made up almost entirely of the mineral collophane, ($3Ca_3(PO_4)_2$ n Ca (CO_3, F_2, O, SO_4), H_2O)x n = 1 to 2.), a hydrous calcium carbonate phosphate. It is interesting to note the apparent presence of considerable collophane. There are also other similarities between the two:

Collophane	*Coprolites* (Fish)
Amorphous.	Amorphous.
Color: variable.	Color: variable.
Specific gravity 2.6–2.92	Sp. Gr. (of those weighed) 2.65–2.78)
Fuses on edges and turns white.	Fuses slightly and turns light in color.
Soluble in HNO_3 with effervescence.	Soluble in HNO_3 with effervescence.
Chemical Compo., $3Ca_3(PO_4)_2$ .n Ca (CO_3, F_2, O, SO_4) (H_2O)x n = 1 to 2	Chemical Compo., varied amounts of SiO_2, FeS_2, Al_2O_3, $CaCO_3$, $Ca_3(PO_4)_2$, with small amounts of carbonaceous matter and H_2O.
Small amounts of Al., Fe., and Mg. may replace Ca.	

[9]The excess of iron sulphide in sample No. 2 is due to an external coating of iron pyrites. P. H. Price.

[10]Mineralogy and Petrography of Fossil Bone, Bull. Geol. Soc. Amer., Vol. XXXV, 1924, pp. 535–556, pls. 26–29.

The associated elements are therefore, calcium, silica, iron, alumina, and a small amount of carbonaceous material. Tests were not made for the other elements, fluorine, and magnesium, but it is highly probable that traces would have been found.

TEETH, SCALES, AND OTHER REMAINS FOUND ASSOCIATED WITH THE COPROLITES.

Teeth of the Paleoniscus-type. Numerous teeth and scales of fishes were found in the same bed as the coprolites, which have been described in the preceding pages and illustrated upon Plates XI–XVIII.

As has been already stated (See page 221) it has been thought to be likely that many of the coprolites should be referred to the genus *Paleoniscus.* The teeth which are by the writer attributed to the same genus are common in the dark shale overlying the "Coprolite Limestone Horizon." They are found dissociated from any other part of the skeleton, indicating that they may have been often dropped out long before the death of the fish itself. They also occur in the coprolites themselves (See Plate XV, fig. 3). Most of these teeth are smooth, slightly curved, acute at the tip, and expanded toward the base. In some of the teeth the apex is more acute than in others being almost as sharp as the point of a needle, while a few are rounded at the apex. Those which are especially sharp have a transparent enamel-like apex, while those which are rounded do not. It seems that in the latter the sharp point has been either broken or worn off, so that the apex is now blunt or rounded. (See Plate XIX, figs. 6, 11, 30–32, 35–37, and 42.)

These teeth plainly show the pulp-cavity at the base, conformed to the general outline of the teeth, and extending inwardly about one-third of the length of the tooth.

The length of these teeth varies from .94 mm. to 3.25 mm. *Paleoniscus* is one of the most widely known of the ganoid fishes, which

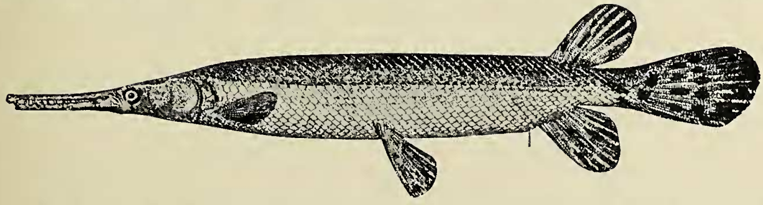


FIG. 4. The Short-nosed Gar-pike *Lepidosteus platystomus* Rafinesque. 1/6 nat. size. Mississippi Basin. (After Goode).

existed from the later Paleozoic into the Mesozoic Age. Its remains are abundant in certain formations. It belongs to the ganoid fishes. Living representatives of this group are the Gar-pike, the Sturgeon, and *Amia*, the Bow-fin.

Newberry in speaking of the genus to which the writer ascribes much of the material collected says: "*Paleoniscus* includes twenty or more species, ranging from the Sub-Carboniferous to the Trias. They have fusiform bodies, rhomboidal scales, heterocercal tails, a single dorsal fin, fulcral spines on the anterior margin of all the fins. Their teeth are numerous, conical, and acute. In some species the scales are highly ornamented, in others plain and polished. It was formerly supposed that Carboniferous species generally had plain scales, while those of the Permian were striated. This is now known to be incorrect, as most of the Carboniferous have ornamented scales and head-plates."

We give here illustrations of two species of *Paleoniscus*, the first (Text fig. 5) being that of a species found in Ohio.

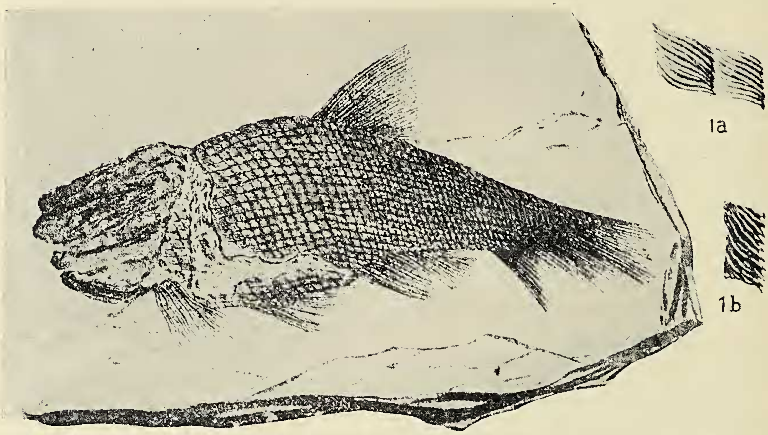


FIG. 5. *Paleoniscus peltigerus* Newberry. 1a, 1b, scales of the same. (Reproduced from Vol. I, Paleontology of Ohio.)

The second species (Text fig. 6) represents a restoration of a species found in Europe.

Ganoid Scales. Associated with the teeth which the writer has referred to the genus *Paleoniscus* are occasionally found scales of the rhomboid type which are characteristic of the ganoid fishes. These are either smooth or striated. In text-figure 7 is given at *A* a drawing

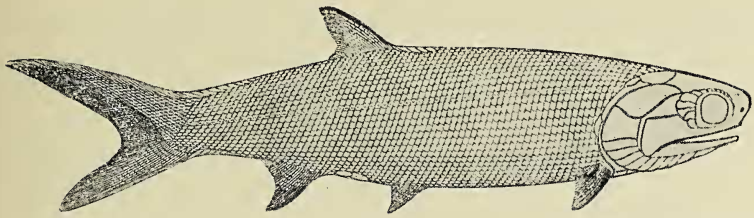


FIG. 6. Restoration of *Paleoniscus macropomus* from the Upper Permian of Germany. (After R. H. Traquair.)

of a smooth scale and photographic magnifications of three scales of this description contained in the collection upon which this paper is based.

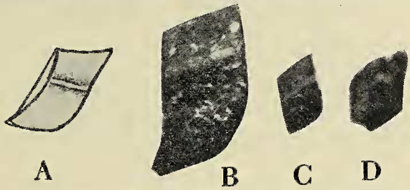


FIG. 7. A. drawing of smooth rhomboid scale of ganoid type; B. C. D, photographs of scales of same type. Magnified about 5 diam.

The rhombic scales which have a more or less striated surface are represented in text-figure 8. The first illustration in this cut (A) is a drawing of a cluster of scales, showing their arrangement in life, and figure (B) is a drawing showing the usual arrangement of the striæ on an individual scale. The other figures on the cut (C–J) show various scales from the collection all magnified about five diameters.

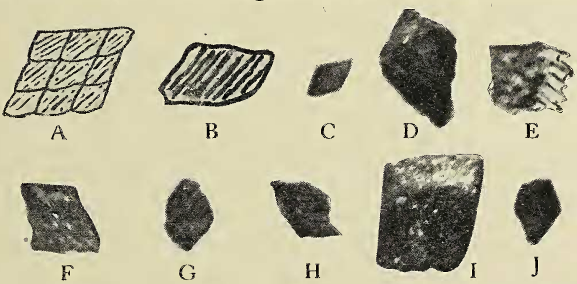


FIG. 8. A, cluster of ganoid scales; B, enlarged drawing showing location of striæ; C–J, various striated scales in the collection, Magnified about 5 diameters.

The scales figured in the foregoing text-figures may represent differences due to location on various parts of the body of the fish, or they may represent two or more species of *Paleoniscus*.

Teeth of the Diplodus-type. In the same deposits and intermingled with the teeth attributed to *Paleoniscus*, but far less numerous, are teeth which the writer attributes to the genus *Diplodus.** (See Plates XX and XXI.) The fishes which possessed these teeth were related to *Pleuracanthus*[11] and are classified as belonging to the *Selachii*, or sharks. We give in text-figure 9 a restoration of a species of *Pleuracanthus* from the Lower Permain of Bohemia.

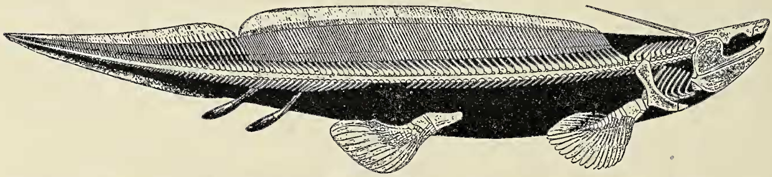


FIG. 9. Restored skeleton of *Pleuracanthus decheni* from the lower Permian of Bohemia, about one-seventh natural size. (After A. Fritsch, except that the paired fins have been reversed in direction). From "A Guide to the British Museum, 1905, p. 66.

In the teeth of this type there is considerable variation in size, but all retain in general the same characteristics, so that they may be grouped under the same genus. The variance in size is probably due to differences in the age and size of the fishes of which they were originally a part. (See Plates XX and XXI.)

The teeth of these shark-like fishes consist of a rounded or somewhat oval bony plate, from the anterior edges of which project two lateral denticles, and a small median denticle (See Plate XX). In the case of many of the specimens the denticles have been broken off, but from those which are present the edges of the denticles are shown to be serrate. Often the denticles are slightly curved, while

*NOTE. It is but proper to call attention to the fact that the genus *Diplodus* Ag. is preoccupied and does not stand. O. P. Hay (Cat. Foss. Vert. of N. A., p. 265) accepts *Dittodus* Owen, for *Diplodus*, designating *Dittodus divirgens* Owen = *Diplodus gibbosus* Ag., as the type. Jordan (Genera of Fishes, Part II, p. 213) seems to reach no positive decision as to what name should replace *Diplodus*. It seems, however, that O. P. Hay has solved the difficulty in the most logical manner, if there has been no error in his identifications, and the name *Dittodus* throughout this paper should probably replace the name *Diplodus*. W. J. HOLLAND.

[11] *Pleuracanthus* is preoccupied in the *Coleoptera*, Gray, 1832. It has been replaced (*fide* D. S. Jordan) by *Diacranodus* Garman. Jordan suggests that *Orthacanthus* Ag. may be equivalent to *Pleuracanthus* Ag., which latter name is excluded from the nomenclature of ichthyology. W. J. H.

the angles formed by the union of the denticles to the bony base are sometimes unequal. On the lower side of the base and immediately opposite the median denticle there is a rounded horn-like, bony projection (See fig. 10, A, and Plate XX, fig. 4). On the upper side, or the same side as the denticles, but at the opposite or posterior end is a bony projection that is flattened on the top, which served as a crushing surface (Fig. 10, B; and Plate XXI, figs. 13–16 at D).

There are four dental tubuli present, arranged in pairs, one pair entering the bony plate from the under side near the center, and the remaining pair entering at the posterior end, just beneath the crushing surface. (See Plate XX, fig. 3.)

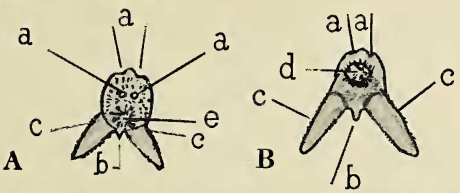


Fig. 10. Diagrammatic outlines of inferior and superior faces of tooth referred to *Diplodus*.
A, inferior view; B, superior view. Both views are drawn looking at the teeth from in front, with the denticles, which in the jaw of the fish pointed forward, pointing downward on the cut. *a*, *a*, paired tubuli or foramina; *b*, small median denticle; *c*, serrated edges of denticles; *d*, bony crushing tubercle on upper surface of dental plate; *e*, rounded horn-like projection on under surface of dental plate.

CONCLUSIONS.

The collection of material for this paper has brought together the largest assemblage of fish coprolites of which the writer has knowledge. Along with the coprolites are found well preserved fish scales of the smooth and striated rhombic types, and also two distinct classes of fish teeth, those which are small and conical, being of the *Paleoniscus*-type; and those with plates and denticles, being of the *Diplodus*-type. Along with these were a few spines (See Plate XX, fig. 3.)

Several of the coprolites show evidence of having been bored into by some dung-eating animal, while the excrement was still in a soft state.

It is the belief of the writer that there is a relation between the number of turns in the digestive tracts of fishes to the number of turns in the excrement, because of the association of the two general types of excrement with the two types of the teeth of fishes.

The two large coprolites on Plate XVIII, figs. 1 and 2 found associated with the other material described in this paper, and containing rhombic fish scales of the ganoid type, because of their great dissimilarity to the coprolites of fishes depicted on the plates, and the fact that both amphibian and reptilian remains have been discovered at approximalely the same horizon near Pittsburgh, are supposed to be of amphibian or reptilian origin, or both. Fig. 1, may be reptilian; fig. 2, amphibian.

From the chemical analyses it would seem that between the mineralogy and petrography of coprolites and of fossil bone there is a similarity.

It is hoped that further search may reveal more perfect remains, or even entire skeletons, or show cause for their absence.

ACKNOWLEDGMENTS.

Before concluding this paper I desire to make acknowledgment of those who have aided me. The study was made possible by the encouragement of Dr. I. C. White, State Geologist of West Virginia. I owe much to the helpful suggestions of Dr. John L. Tilton; the chemical analyses were made by Dr. B. B. Kaplan; the photographic work was done by Professor J. V. Ankeny. Finally I wish to express my thanks to Dr. W. J. Holland, the Editor of the publications of the Carnegie Museum, who carefully went over the manuscript with me and arranged the plates.

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EXPLANATION OF PLATE X.

REPRODUCTION OF MORGANTOWN QUADRANGLE, U. S. GEOLOGICAL SURVEY.

Scale: 1 inch = 1 mile. Localities indicated by heavy-faced numbers.

1. Excavation for the foundation of the Stadium of the West Virginia University (now covered by the Stadium). 880 B.
2. Keck's Quarry, Westover. 890 B.
3. Athletic Field of New High School. 900 B.
4. Morgantown Brick Plant. 850 B.
5. Red Bridge near Fairmor. 885 B.
6. Ravine below fill, East Morgantown. 885 B.